DOCUMENT RESUME

ED 197 958 SE 034 021

AUTHOR Anderson, Charles W.: Barufaldi, James P.
TITLE Research on Elementary School Science Teaching: A Study Using Short-Term Outcome Measures.
INSTITUTION Michigan State Univ., East Lansing. Inst. for Research on Teaching.
SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.
REPORT NO IRT-OP-37
PUB DATE Oct 80
CONTRACT 400-76-0073
NOTE 33p.: Contains occasional light and broken type.
AVAILABLE FROM Inst. for Research on Teaching, College of Education, 252 Erickson Hall, Michigan State Univ., East Lansing, MI 48824 ($2.75).

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Classroom Observation Techniques; Elementary Education; Elementary School Science; *Elementary School Teachers; Science Course Improvement Projects; Science Education; *Science Instruction; Teacher Developed Materials; *Teaching Methods
IDENTIFIERS Science Education Research

ABSTRACT

Presented are the results of an exploratory study in which methods used in research on teaching were adapted to research on elementary school science teaching. An observation system was designed that enabled an observer to record detailed, context-specific information about the behavior of teachers (N=22) and students in grades 2-5 during elementary school science lessons. Short-term outcome measures were also collected concerning the observer's and the teachers' perceptions of each lesson. Lack of planning time and limited knowledge of science were felt to contribute to the avoidance by elementary school teachers of manipulable science materials as well as their reluctance to use complicated instructional techniques. Potential uses of the short-term outcome measures are discussed. (CS)

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Occasional Paper No. 37

RESEARCH ON ELEMENTARY SCHOOL SCIENCE TEACHING: A STUDY USING SHORT-TERM OUTCOME MEASURES

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Published By

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252 Erickson Hall
Michigan State University
East Lansing, Michigan 48824
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The Science and Mathematics Teaching Center
E-37 McDonel Hall
Michigan State University
East Lansing, Michigan 48824

Printed and Distributed
by the
College of Education
Michigan State University

October 1980

Publication of this work is sponsored by the Institute for Research on Teaching, College of Education, Michigan State University. The Institute for Research on Teaching is funded primarily by the Program for Teaching and Instruction of the National Institute of Education, United States Department of Education. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the National Institute of Education. (Contract No. 400-76-0073)

This paper is also available as Science and Mathematics Teaching Center Technical Report Number 80-9.

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Abstract

An observation system was designed that enabled an observer to record detailed, context-specific information about the behavior of teachers and students during elementary school science lessons. Short-term outcome measures were also collected concerning the observer's and the teachers' perceptions of each lesson.

The observed teachers had little planning time and limited knowledge of science. As a result complicated instructional techniques such as those involving manipulable science materials were either avoided by the teacher or used less successfully than simpler techniques.

The short-term outcome measures have many potential uses. The observation system and results are of interest to science educators.

RESEARCH ON ELEMENTARY SCHOOL SCIENCE TEACHING: A STUDY USING SHORT-TERM OUTCOME MEASURES[1]

Charles W. Anderson and James P. Barufaldi[2]

Objectives of the Study

Recent research on teaching has produced important advances in both methods of studying classrooms and understanding of them. Most of this research, however, has concentrated on language arts and mathematics instruction. In this paper, we describe an exploratory study in which we adapted the methods used in research on teaching for research on elementary school science teaching.

The specific objectives of the study were as follows:

1. To develop a classroom observation system appropriate for use with elementary school science lessons.
2. To develop reliable and valid short-term outcome measures that can be collected quickly and unobtrusively on a lesson-by-lesson basis.
3. To use the observation system and the outcome measures for the the analysis of elementary school science lessons.

The observation system was designed to provide information on how teachers cope with two types of tasks that characterize every science lesson. The first of these tasks was *classroom management*, controlling student behavior and using materials so students can work efficiently on their assigned tasks. The second was *information structuring*,

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[1]Paper presented at the annual meeting of the American Educational Association, Boston, 1980.

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organizing the information available to students (often from many different sources) to create meaningful learning opportunities.

Recent Research on Teaching: How Applicable to Science Instruction?

There have been important advances in research on teaching in recent years. Naturalistic studies such as those by Stallings (Note 1), Brophy and Evertson (1976), and Good and Grouws (1977) have served as the basis for successful experimental studies (e.g., Anderson, Evertson & Brophy, 1979; Good & Grouws, 1979). The results of these experimental studies indicate that research on teaching can contribute to the development of training procedures that help teachers to increase the achievement of their students.

There are, however, some important limitations to this body of research as it now stands. Some of those limitations are addressed in the design of this study.

First, most of the important research on teaching has concentrated on the "basic skills" areas of reading, language arts, and mathematics. For this study, an observation system was developed that is appropriate for use in elementary school science lessons. It contains special categories that enable an observer to record aspects of the way teachers approach the task of organizing lessons where manipulable science materials are used.

Second, much of the recent research on teaching has relied on methods that involve averaging values of classroom behavior variables and outcome measures across lessons for each teacher. Analyses conducted in this way produce information about why some teachers are generally more successful than others. However, the comparison of lessons rather than teachers is also of considerable interest. Curriculum developers, for instance, need to know about the characteristics of lessons that can

be taught successfully by most teachers. The short-term outcome measures used in this study make it possible to use the lesson rather than the teacher as the unit of analysis.

Finally, much research on teaching has relied on student achievement test gains as outcome measures. Although student learning is obviously an important outcome of instruction, there are no widely accepted tests of students' general achievement in science. Furthermore, tests of student learning do not address some of the most important problems in elementary science education today. The National Science Foundation (NSF) has recently sponsored a series of studies on the status of pre-college science education in United States schools (Dorose, Lockard, & Pauldy, 1979; Stake & Easeley, Note 2; Weiss, Note 3). These studies have confirmed the following:

1. little or no science instruction takes place in many elementary school classrooms,
2. many teachers feel inadequately prepared to teach science, and
3. science instructional materials developed and disseminated with aid from the NSF have not been accepted by many elementary school teachers.

Thus, the reluctance of elementary school teachers to teach science is at least as serious a problem as the nature of instruction when it occurs. This suggests that the teacher's satisfaction with the lesson must be regarded as an important outcome of instruction.

In order to achieve a meaningful evaluation of the success of each lesson, the following types of outcome measures were used:

1. the teacher's perceptions of the success of the lesson,
2. student behavior during the lesson (specifically, the average proportion of students observed off-task), and
3. the observer's ratings of the lesson's success.

Method

Setting

The setting for this study was a small, suburban school district near Austin, Texas. Most of the students in this district were white, and most came from middle- to upper middle-class families. Achievement on standardized tests was well above national norms. Observational data were collected during the 1978-79 school year.

The 22 observed teachers included all the teachers in grades two through five who taught science. They were distributed as shown in Table 1.

Table 1.

Teachers Whose Classes Were Observed

	Grade			
	2	3	4	5
Number of Teachers	5	7	6	1
Number of Instructional Aides	1	0	0	0
Number of Student Teachers	0	0	2	0

The teachers in the second-grade used materials from the Science Curriculum Improvement Study (SCIS). The SCIS curriculum emphasizes the use of manipulable materials and hands-on experience, generally with class discussions to reinforce and structure what the students learn. Books and audio-visual materials were rarely used.

Teachers in the third, fourth, and fifth grades used a variety of materials, including locally developed materials, textbooks, and audio-visual materials. Lessons in the third and fourth grades included fewer experiences with manipulable materials than second grade lessons. The fifth-grade teacher, who was the only science specialist among the

observed teachers, used a wide variety of manipulable materials, books and audio-visual materials.

The Observation System: Descriptive Data

The observation system used in this study was developed by Charles Anderson over a period of nine months. It was based on the following three sources of information:

1. Observation systems used for other studies, in particular those used for two studies conducted by the Correlates of Effective Teaching Program at the University of Texas Research and Development Center for Teacher Education (Brophy & Evertson, 1976; Evertson, Anderson, Anderson, & Brophy, 1980).

2. A review of research on classroom processes in which promising variables or areas for investigation were identified (See Anderson, Note 4).

3. Classroom observations in which preliminary versions of the observation were tested and modified according to their appropriateness to the setting and to the research questions.

In its final form, the observation system provided a rich data base (mostly numerical) that described the 57 observed science lessons. A full report on this data base is given by Anderson (Note 4). It includes several measures not reported in this paper, such as narrative descriptions of the lessons, the teachers' objectives for each lesson (as described by both teachers and observers), teachers' procedures for directing the use of manipulable science materials, teachers' methods of structuring information available to the students, and student behavior during seat work (Anderson, Note 1).

Descriptive data which are reported in this paper include the following:

1. *Classroom descriptions* were "snapshots" of the room taken at 10-minute intervals. Every 10 minutes the observer scanned the room and described the classroom organization or format, the instructional materials being used, the noise level of the classroom, the location and activity

of the teacher, and the activity of each student.

2. The organization of the classroom during each lesson was characterized by recording how much time was spent during the lesson in each of 12 *classroom organizational formats*, such as whole-class discussions, small groups working on the same task, small groups working on different tasks, or transitions.

3. The *instructional materials* used during each lesson were characterized in a similar manner. Fourteen categories were used to describe materials in use, including books, worksheets, manipulable science materials, and no materials.

4. During *class discussions* the observer recorded information about the teachers' statements and questions, and the activities of the students. Student on-task activities included raising hands to volunteer, answering questions asked by the teacher, and making relevant comments about the topic of the discussion. Off-task activities such as making irrelevant comments, social talking, and misbehavior were also recorded.

Although all data reported in this study were recorded by a single observer, a second observer was trained for the purposes of assessing the reliability of the system. The two observers observed and independently recorded data for 11 lessons. Reliability was assessed independently for each category in the observation system using procedures described in the section on data analysis.

Outcome Measures

Three types of measures were used to evaluate the success of the observed lessons.

Teacher ratings. After each of the observed lessons the teacher rated the success of the lesson according to three criteria: the students' enjoyment of the lesson, the ease of classroom management during the lesson, and the teacher's overall satisfaction with the lesson.

The teacher ratings were selected as outcome measures for two reasons. First, teachers are most likely to continue using materials and methods that have worked well for them in the past. Second, teachers are more familiar with their classrooms than anyone else, so their per-

perceptions of success are likely to have considerable validity.

Student behavior. The average proportion of students off-task was calculated for each of the observed lessons. This was selected as an outcome measure because of the well-documented association between measures of student learning and student on-task behavior in a variety of different teaching situations (Berliner, 1979; Rosenshine, 1979; Brophy, Note 5).

Observer ratings. After each lesson the observer rated the success of each lesson according to three criteria: student learning, student enjoyment, and the efficiency with which the teacher managed the classroom.

The observer ratings were selected as outcome measures for two reasons. First, they provided information that could be used to assess the validity of the other outcome measures. Second, the observer was an experienced elementary school science teacher and was familiar with the science program materials being used by the teachers, so his perceptions of success were likely to have considerable validity.

Procedures used to assess the reliability and validity of the outcome measures are described in detail by Anderson (Note 1). Inter-observer reliability was .74 for the proportion of students off-task and .86, .90, and .87 for the three observer ratings. The possibility of "observer drift" in the ratings was also checked by having the observer re-evaluate five lessons on the basis of the narrative notes and other information from the original observation forms. The elapsed time between the first and the second ratings was from three to six months, and the second ratings were done "blind" to the first. Fourteen of the 15 pairs of ratings agreed within one point on a nine-point scale.

Since there was never more than one teacher in the classroom, inter-observer reliability could not be calculated for the teacher ratings.

However, the teacher ratings did correlate highly with observer ratings of the same characteristics of the lessons, especially when methods were used that compensated for the effects of different rating sets used by different teachers.

Data Analysis

The lesson was the unit of analysis for this study. The data from the observation system were used to generate 234 classroom behavior variables, each of which described some small portion of the events during a given lesson. All of the classroom behavior variables in combination provided a detailed, multidimensional description of each lesson. Thus, descriptive data from the observation system can be used to answer the question, "What were the observed lessons like?"

The question, "How were more successful lessons different from less successful lessons?" could be answered by looking at relationships between the classroom behavior variables and the outcome measures. Two types of relationships were calculated, as follows:

1. *Simple correlations* between each of the classroom behavior variables and two types of outcome measures (student behavior and observer ratings) were calculated. These correlations answer the question, "How were the more successful lessons different from the less successful lessons, regardless of who was teaching?"

2. *Linear regression* models which examined the relationship between within-teacher variation for each classroom behavior variable and two types of outcome measures (student behavior and teacher ratings). This method of analysis answered the question, "For a given teacher, how were more successful lessons different from less successful lessons?"

Reliability was assessed by calculating inter-observer correlations for each of the 234 classroom behavior variables. Variables whose reliability correlations were not significant at the .05 level (equivalent to $r = .55$ for 11 lessons) are marked with a question mark in the tables. Most of the variables that failed to achieve this criterion described very low-frequency events.

Results

General Descriptive Information

The results are based on the observation of 57 science lessons taught by 22 teachers. Fourteen of those lessons were taught to second-grade students, 22 to third-grade students, 18 to fourth-grade students, and three to fifth-grade students. The average number of students present was 22.7. Lesson length ranged from 23 to 86 minutes. The average lesson was 39.5 minutes long.

Most of the observed teachers taught science in the afternoon. Although the school day started at 8:00 a.m. for most students, only two of the observed lessons began before 10:00 a.m., while 43 began after 1:00 p.m.

Relationships Among Outcome Measures

The relationships among the seven variables used as outcome measures are summarized in Table 2. Figure 1 contains an explanation of the symbols used in Table 2 and Table 7.

1. Variable Description

More complete information about each variable can be found in Anderson (Note 1).

2. Reliability

A blank indicates $p \leq .05$ for the reliability correlation for that variable.

(?) indicates $p \geq .05$ for the reliability correlation.

3. Means

The tables include information concerning units of measurement for each variable.

4. Correlations

Blank	correlation with $p > .10$
.35, -.35	correlation with $.05 \ p \leq .05$
* * .45, -.45	correlation with $.01 < p \leq .05$
** ** .55, -.55	correlation with $p \leq .01$

5. Results of linear models within-teacher analyses

Blank indicates a relationship between classroom behavior variable and outcome measure with $p > .10$

+, -	relationship with $.05 < p \leq .10$
* * +, -	relationship with $.01 < p \leq .05$
** ** +, -	relationship with $p \leq .01$

Figure 1. Symbols used in Tables 2 and 7.

TABLE 2

Significant Correlations Among Outcome Measures

Variable Description	Means	Reliability	Correlations: Off-Task	Learning	Enjoyment	Management	Within Teacher: Student Enjoyment	Satisfaction	Management	Off-Task
Observer's rating of overall student learning	5.5		** -.47	** 1.00	** .57	** .52		+	* +	** -
Observer's ratings of overall student enjoyment	6.2		* -.33	** .57	** 1.00	** .46	** +	+		
Observer's rating of overall management efficiency	6.3		** -.75	** .52	** .46	** 1.00	* +	* +	** +	** -
Lesson average proportion of observed students off-task	.20		** 1.00	** -.47	* -.33	** -.75				** +
Teacher's rating of overall student enjoyment	7.1	na			** .35		** +	** +		
Teacher's rating of overall satisfaction	6.2	na	-.22	** .35	** .37	** .42	** +	** +	** +	
Teacher's rating of overall management difficulty	6.4	na	-.25	.23		** .54		** +	** +	

The teachers and the observer generally agreed about the success of the observed lessons, and the lessons that were perceived as successful according to one criterion tended also to be successful according to the other criteria. This pattern held for both methods of analysis used: simple correlations among measures and analyses using only within-teacher variance.

Variables which measured similar attributes of lessons tended to be more closely associated with each other than with other variables. This pattern held both for the two variables describing student enjoyment and for the three variables describing management success (proportion of students off-task, observer's ratings of management success, teachers' ratings of ease of management).

The teachers' ratings of overall satisfaction tended to be more closely associated with the observer's ratings of success in management than with the observer's ratings of student learning. This was one of a number of relationships that indicated that the observed teachers were very concerned about maintaining order in the classroom--perhaps more concerned than the observer.

At least one other study of elementary school science teaching (Sendelbach & Smith, Note 6) indicates that high levels of teacher concern about management of science lessons may be a common phenomenon. This concern is probably appropriate; management success has consistently been associated with teaching effectiveness (Rosenshine, 1979; Brophy, Note 5). The difficulty of controlling students and materials during hands-on experiences may also contribute to teachers' management concerns.

These management concerns apparently affect teachers' instructional decisions in a variety of important ways. Some of those effects are

effects are discussed below, in the sections describing teachers' choices of classroom organization and instructional materials.

Student Activities

During each of the observed lessons, the observer completed a classroom description every 10 minutes; the classroom descriptions included observation and classification of the behavior of each student in the classroom. In all, 212 classroom descriptions were completed. Summary statistics describing observed student behavior are presented in Table 3.

Table 3

How Observed Students Spent Their Time in Science Classes

Activity	Proportion of Total Time
On-Task Behavior	
Listening	.58
Writing	.09
Using science materials	.06
Talking about lesson-related matters	.03
Procedural tasks	.01
Reading assigned material	.01 (?)
Off-Task Behavior	
"Doing nothing" (off-task, but not disturbing others)	.13
Social talk	.08
Misbehaving	.003 (?)

(?) Indicates variables with low-reliability correlations.

The students spent much of their time listening to the teacher or to other students. They also spent a considerable amount of time in such off-task activities as doing nothing and social talking. This does not indicate that the observed classes were chaotic (they generally were not) or that students often failed to complete assigned work. Rather, most classes usually had a few students off-task; there were periods during most classes when many students had nothing to do. They waited to sharpen pencils, for the teacher to answer their questions, for materials to be distributed or picked up, and for a new activity to begin after they had finished one.

Some teachers were much more successful than others in minimizing the amount of time that students spent off-task. Also, some instructional decisions or styles of teaching made it easier for the teachers to minimize student off-task behavior. Some of those decisions and their implications are discussed in the next section.

Students used manipulable science materials in 25% of the observed lessons, but only 6% of the observed student time was spent in using manipulable science materials. This is a reflection of the fact that even in hands-on lessons the students spent most of their time doing other things, such as listening to instructions, discussing their results, waiting for materials to be distributed, or cleaning up.

Teachers' Choices of Classroom Organization

The first column of figures in Table 4 indicates the proportion of time the teachers allocated to a variety of classroom organizational formats.

Table 4

Teachers' Choices of Classroom Organizational Formats

Format	Proportion of Time Allocated	Proportion of Students Off-Task
Whole-class academic activities	.64	.14
Transitions	.09	.62
Students working individually on the same task	.08	.25
Whole class using audio-visual materials	.07	.20
Students working in small groups on the same task	.03	.32
Procedural directions	.03	.18
All others*	.03	.20 - 1.00

* Student presentations, students working individually on tests, students working individually on different tasks, small groups working on different tasks, dead time, and "other."

Very few lessons were observed in which the format stayed the same for the entire period. A typical materials-oriented lesson, for instance, might have proceeded as follows:

1. Whole class discussion of the problem for the day.
2. Procedural directions regarding use of materials.
3. Distribution of materials (coded as a transition).
4. Students work individually with materials.
5. Clean-up and return of materials (coded as a transition).
6. Whole-class discussion of the results of the students' investigations.

Guiding a group of elementary school students through a sequence like that is not a trivial organizational task. Some teachers accomplished it better than others.

The second column in Table 4 indicates that student management was easier in some formats than in others. The teachers tended to be most successful in controlling student behavior during whole-class discussions, an average of 14% of the students were observed off-task. The teachers also allocated almost two-third of the observed classtime to this format.

The preponderance of whole-class discussions may have been at least partly subject-matter specific for the observed teachers. Several of them indicated in informal conversations that they depended on other forms of classroom organization, such as reading groups or individual seatwork, while teaching other subjects. Research on teachers' choices of classroom organization in other subjects (Anderson, Evertson, & Brophy, 1979; Good & Beckerman, 1978) has generally found a higher incidence of individual seatwork and small-group activities. The teachers depended on science program materials that did not encourage individual seatwork or ability grouping, though the materials sometimes suggested that teachers have students work in small groups.

Transitions were unavoidable in most of the observed lessons--the alternative was the monotony of doing the same thing for an entire period. Transitions were often a source of management problems, however, On the average, 62% of the students were off-task during the observed transitions.

Teachers' Choices of Instructional Materials

The instructional materials used in the observed lessons and their effects on student off-task behavior are summarized in Table 5.

Two facts are apparent from Table 5. First, there was considerably more variety in teachers' choices of materials than of classroom organizational formats. Second, choices of materials had less effect on the proportion of students off-task than did choices of classroom organization. These two facts are probably connected; the teachers were more

willing to use a variety of materials because no one choice was clearly superior.

Table 5

Teachers' Choices of Materials for Teaching Science Lessons

Type of Materials	Proportion of Time Allocated	Proportion of Students Off-Task
No materials	.34	.20
Manipulable science materials	.12	.22
Books	.12	.12
Worksheets not made by teacher	.11	.20
Mixed non-manipulable materials	.08	.20
Students' own paper or notebooks (?)	.04	.19
All others*	.12	.04 - .64

* Mixed materials including manipulable science materials, records or audio tapes, tests, workbooks, teacher-prepared worksheets, art materials, games or puzzles, "other."

(?) Indicates variable with low-reliability correlation.

The teachers reported significantly ($p < .01$) less overall satisfaction with lessons in which their students used manipulable science materials than with lessons in which they did not. Teachers' ratings of student enjoyment and management difficulty were also marginally lower ($p < .10$), and there were significantly ($p < .05$) more students off-task in lessons during which students used manipulable science materials. The increase in off-task behavior was due primarily to the fact that transitions tended to be longer and more frequent in hands-on lessons, and rates of student off-task behavior tended to be very high during transitions (see Table 4).

Class Discussions

Teachers allocated more time to class discussions than to all other forms of classroom organization combined. Even in those lessons where other classroom organizational formats were used, a portion of the period was generally spent in class discussion. Only six of the 57 observed lessons included five minutes or less of whole-class academic activity.

Whole-class academic activities in the observed classes could almost always be described more accurately as discussions or recitations than as lectures. The teachers rarely talked for sustained periods without interruption, and rates of student participation and activity were generally high.

The rates at which teachers and students engaged in various types of activities were calculated by dividing the time spent in class discussions into three-minute segments. Thus, all of the data presented in this section are rates per three minutes of class discussion. Only 42% of the three-minute segments during the observed classes contained as much as 30 seconds of continuous teacher talk. Teacher questions were much more common. Eighty-three percent of the observed time segments contained at least one teacher question. The rates at which a variety of student activities were observed are presented in Table 6.

It is apparent from Table 6 that students were active during discussions in a variety of ways. Some of those ways of participating, such as volunteering to answer questions or making relevant comments, were generally sanctioned by the teachers. Others, such as social talk and misbehavior, were generally regarded with disfavor. Student callouts and irrelevant questions or comments met with varied reactions from the observed teachers, who sometimes disapproved and sometimes treated them as legitimate contributions to the discussions.

Relationships between variables describing class discussions and outcome measures are summarized in Table 7.

Table 6

Student Activities During Class Discussion

Activity	Number of Students
Volunteered by raising a hand	7.2
Called out an answer, question, or comment	2.3 (?)
Responded to a teacher's question as a volunteer	3.3
Participated in a choral response	6.2
Participated in a voting response	4.7
Responded to a teacher's question as a nonvolunteer	.2
Responded to a teacher's question in writing	0.0 (?)
Made a relevant question or comment	1.2
Made an irrelevant question or comment	.6
Talked continuously for 10 seconds or more	.8
Talked socially	3.3
Misbehaved	.1 (?)

Note: The number of students is the average number of those who engaged in each activity during a three-minute time segment.

(?) Indicates variables with low-reliability correlations.

Table 7

Relationships Between Outcome Criteria for Selected Variables Describing Activities During Lecture-Discussion

Variable Description	Means	Reliability	Correlations: Off-Task	Learning	Enjoyment	Management	Within Teacher: Student Enjoyment	Satisfaction	Management	Off-Task
Part A: Teacher behaviors										
Proportion of segments with process questions	.44			.28		* .40	** +	* +	+	-
Proportion of segments with teacher questions	.83						* +		+	
Part B: Student behaviors										
Lesson average rate of students raising hands to volunteer	7.2 *			* .39	* .40	* .38	** +	+	+	
Lesson average rates of volunteer responses	3.3 *							+	* +	
Lesson average rate of irrelevant student questions or comments	.6 *	?	** .53	* -.35	* -.41	** -.79	* -	* -		
Lesson average rate of individual student responses, questions, or comments	4.7*	?	* -.34	.31	* .33	.30		* +	** +	* -

(Table continued on next page)

(Table 7 continued)

Variable Description	Means	Reliability	Correlations: Off-Task	Learning	Enjoyment	Management	Within Teacher: Student Enjoyment	Satisfaction	Management
Lesson average rates of students off-task during lecture or discussion	4.0 *		** .62	* -.41	** -.48	** -.88	** -	-	-

*Rates are per three minutes of class discussion.

In combination, these relationships give a picture of the types of class discussions that the teachers preferred to have.

Process questions are questions that require explanations from students rather than single-word or phrase answers. The use of process and higher-cognitive-level questions has been widely recommended, but evidence regarding their effectiveness in promoting student learning has been quite ambiguous (Winne, 1979; McGlathery, 1978; Rosenshine, 1977). The evidence from this study indicates that the observed teachers preferred lessons in which they asked process questions.

When teachers failed to ask process questions, it was often because they had not created a classroom context in which such questions would be appropriate. Teachers would ask few process questions, for instance, when many students were not paying attention, or when students did not understand basic facts about the topic of discussion. Thus, it would seem that the investigation of higher-cognitive-level questions in classrooms should include increased attention to the contexts in which such questions are asked.

Both the teachers and the observer preferred lessons in which many students participated actively while staying within the classroom rules. Predictably, irrelevant questions or comments, social talk, and other types of off-task behavior were regarded negatively by both the teachers and the observer.

Both the teachers and the observer tended to give higher ratings to lessons in which rates of individual student responses were high. The teachers often made use of group response modes, such as choral responses or voting responses. Although these response modes increased the rate of student participation, none of the variables describing group responses was significantly associated with the outcome measures.

Discussion

Implications of the Study for Research

Two aspects of this study's design suggest some direction for other research on teaching and learning in classrooms. The first of these was the set of short-term outcome measures used. These measures have a number of advantages over residualized achievement-test gains as indicators of teaching success.

They provide information about a much broader range of outcomes than student test scores, and they can be used for research on subject-matter areas where widely accepted achievement tests are not available, such as science, social studies, or art.

They can be used quickly, unobtrusively, and reliably. The observer ratings and the data on student off-task behavior were incorporated into the observation system. It took the teachers less than five minutes after each lesson to fill out a short questionnaire that elicited both the teacher ratings and information about their objectives for the lesson, the amount of time they spent in planning and cleanup, and other comments. Their reliability compares quite favorably with that of class-average residualized gain scores.

Finally, the use of short-term outcome measures makes possible a number of new approaches to data analysis, including comparisons of individual lessons as reported in this paper.

These advantages are balanced by some important disadvantages. The first of these is that teacher and observer ratings are often based on quite limited information about how students reacted to instruction. This problem is most severe with older students, who are more likely to conceal both their emotions and the state of their knowledge. A second disadvantage is that the biases of teachers and observers are less open

to public inspection than those of standardized achievement tests. This is particularly likely to be a severe problem for large-scale studies where the ratings of many different observers must be standardized. Thus, the short-term outcome measures used in this study are a useful addition to the outcome measures used in other research on teaching, but are not a substitute for them.

The second methodological innovation of this study was the development of an observation system that is uniquely suited for describing elementary-school science lessons. The descriptions provided by the system were detailed and content-specific, and the system contained categories which are of interest to science educators.

The results reported in this paper are of interest to researchers on teaching in all content areas. Results that are of interest primarily to science educators are reported in a separate paper (Anderson & Barufaldi, Note 7.)

A clear implication of this study, however, is that the process of teaching is not the same for all subjects. The teachers who participated in this study reported that they taught different subjects differently; available evidence from other research (e.g., Good & Beckerman, 1978) indicates that this is true.

The teachers also described problems that they generally experienced in other subjects, but felt more strongly about in science teaching. Foremost among these was their lack of knowledge of science content, which often led to difficulties with organizing materials and information to give their students meaningful learning experiences. The sources and implications of teachers' difficulties with science content are focal points for another study now being conducted, which uses a revised version of the observation system that provides additional information about teachers' methods of dealing with the science content of their lessons.

Implications of the Study for Science Education

The 22 teachers who participated in this study did not constitute a statistically representative sample of elementary-school teachers, but many elementary-school teachers teach under similar conditions. Most of the observed teachers taught in self-contained classrooms. They were responsible not only for science instruction, but also for instruction in all of the other subject areas, and for administrative duties, parent conferences, report cards, and more. As a result, they had to prepare and teach their science lessons under considerable time pressure.

Time pressure was not the only factor making science teaching difficult for these teachers. Most of them also had limited backgrounds in science and a limited understanding of some of the scientific concepts that they were teaching.

Under these conditions, it is not surprising that the teachers often chose to use relatively simple instructional techniques such as whole-class discussion, or that many teachers worried more about making sure that the lessons proceeded without disruption than about the fine points of the lessons' science content. The result, nevertheless, was often a style of teaching that many science educators would consider uninspiring at best.

Prepared science program materials played an important role in the observed lessons. Most of the teachers relied on teachers' guides and teaching materials which they had not personally prepared. By doing this, they saved planning time, but sometimes the prepared program materials created problems. In fact, the best materials sometimes created the worst problems. When the observed teachers tried to follow lesson plans that demanded extensive planning time, knowledge of science, or management skill, they were not always successful in implementing them. The failures

were unsatisfactory to the teachers, the students, and the observer.

Overall, the results of this study point to the importance of factors that have traditionally received virtually no attention in research on science teaching. Among those factors are classroom management and teachers' working conditions. They deserve increased attention in both science education research and practice.

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